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AN EVALUATION OF NEPTUNE
A PROGRAM FOR ESTIMATING LIFE-CYCLE COSTS OF OILY WASTE/WASTE OIL COLLECTION, TRANSPORTATION AND TREATMENT SYSTEMS

Prepared For:
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200 Stovall Street
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WASHINGTON ANALYTICAL SERVICES CENTER, INC.
WOLF RESEARCH AND DEVELOPMENT GROUP

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AN EVALUATION OF NEPTUNE - A PROGRAM FOR ESTIMATING LIFE-CYCLE COSTS OF OILY WASTE/WASTE OIL COLLECTION, TRANSPORTATION AND TREATMENT SYSTEMS.

(7)

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EXECUTIVE SUMMARY

This report describes the results of an evaluation of NEPTUNE, a computer based model designed to estimate life-cycle costs for oily waste/waste oil collection, transfer, treatment and disposal systems. We have found that the program can meet its stated accuracy goal of 25 percent relative accuracy, and can also be a valuable aid in identifying oily waste sources.

We have determined that a formal error propogation analysis, omitted during program development, would provide helpful data to the user and indicate the likely confidence levels of the estimates. The principal recommendation of this report is that this be completed and that new tables for error terms be incorporated into the model.

The procedure used to determine the regression relationships ignored the issue of the weight of the points. In some cases, therefore, the smaller values of cost or effluent volume were fitted better while in other cases the larger values were fitted better. The correct procedure would be to assign *a priori* weights to the data according to their anticipated frequency in the estimation case description.

There would be advantages also to allowing a regression within the model over user input statistics to permit local best fits to be obtained. This would contribute towards expanding the possible applications of the program and its derivatives into the design phases.

We have analyzed oily waste sources and determined that bilge dominates the effluent volume, contributing more than 99 percent of the total. We have made two estimates of the Navy-wide bilge generation rate and determined values of 3.34 and 8.04 million gallons per day using P. A. Engineering and NAVSEA data respectively. The former figure is probably more accurate as it is derived from more recent data.

Using bilge volume as a basis, we computed life-cycle cost estimates of 45.45 million dollars per year and 31.84 million dollars per year for the centralized and shipboard treatments respectively. The corresponding figures obtained by another worker using independent weights were 38.85

and 30.77 million dollars per year. After reviewing the surrounding factors, however, we are unable to establish significant cost savings in the shipboard system.

SECTION I

INTRODUCTION

The EG&G Washington Analytical Services Center is pleased to submit this report to NAVFAC giving the results of an effort to assess NEPTUNE, a program for estimating costs of oily waste/waste oil collection, transportation and treatment. The NEPTUNE program was developed by ATAC Corporation for the Civil Engineering Laboratories (CEL), Naval Battalion Construction Center, Port Hueneme, California.

As an estimating and planning aid NEPTUNE presents an entirely new approach to previous procedures that were time-consuming and expensive. Since traditional methods have evolved as part of a complicated and highly developed planning structure, the specific role of a program of the NEPTUNE type has to be carefully identified. The evaluation effort therefore concentrated in two areas:

1) The evaluation of prediction accuracy, and,
2) The determination of useful information products not specifically designated as goal products.

Our concern in the study was not the validation of the detailed operating characteristics of the program but rather with the general confidence that could be placed in the estimations. To this end, a procedure was developed to extrapolate NEPTUNE life-cycle cost evaluations to obtain a Navy-wide cost estimate and this estimate was compared with those produced in other ways.

Section II of this report summarizes the objectives and characteristics of the NEPTUNE code and considers the general merits of the approach. Section III presents an evaluation of the program features both from the standpoint of regression procedure error analysis and the validity of results for the test case application to San Diego Harbor. The Navy-wide estimates generated as part of this work are given in Section IV and Section V presents concluding remarks.

SECTION II

PROGRAM OBJECTIVES AND CHARACTERISTICS

2.1 Objective

The general objective of the life cycle cost task was to develop a method that would permit rapid comparison of relative life cycle costs for alternative oily waste management systems. Promising alternatives identified in this manner would subsequently be evaluated in detail using conventional engineering practices. The method would therefore serve as a combined engineering and economic tool for sorting alternatives. Specific objectives were to achieve the following:

- Accuracy ± 25% on a relative basis
- Adequate method flexibility to permit tailoring to site-specific conditions or needs
- Adequate simplicity to permit use without extensive training
- Compatibility with existing equipment, records, and procedures

Evaluations of the program were therefore required in the four key areas of accuracy, flexibility, simplicity and compatability.

Five partially related development efforts were completed in preparing the program:

1. Identification of individual oily waste sources and their geographic location
2. Estimation of generated oily waste volumes and characteristics
3. Assessment of available technology to include performance, cost, energy, and labor factors
4. Development of system configurations matching sources, treatment, and disposal to achieve compliance with discharge criteria
5. Development of assessment methods incorporating source, technology, and discharge criteria data

The results of the development effort have been discussed in a CEL publication[1] and will not be detailed here. There are important regression relationships involved in the computation of oily waste volumes generated

and the estimation of cost factors to be used in the delivered cost estimates and the validity of these estimations must be assessed.

The method developed for identifying oily waste sources and estimating the waste volumes and characteristics offers potential in other areas as well as yielding useful ancillary data. We therefore have extracted a discussion of these aspects of the problem, and, in so doing, will define the key terms used in the procedures.

2.2 Data Sources and Characteristics

Two existing Navy data files have been adapted for use in NEPTUNE:

1) The Navy Facility Assets (NFA) Data Base

The NFA Data Base was established by the Naval Facilities Engineering Command Facilities Systems Office (FACSO) to maintain data on all real property within the Navy. An automated data processing system is employed for storage, retrieval, and updating of a series of data elements that constitute the Real Property Inventory (RPI). Most data elements pertain to either real property management, facilities planning, or maintenance funding. Certain data elements do, however, provide information that may be applicable to oily waste system evaluation. RPI data elements of interest are:

- Reporting Activity Names. The proper names for Navy activities to which real property accountability has been assigned.
- Reporting Activity Unit Identification Code (UIC). A unique five-number code permanently assigned to each reporting activity. Navy units employ a prefix N, and Marine Corps units employ a prefix M. Use of the UIC rather than the more lengthy activity name facilitates recordkeeping.
- Special Area. A two-letter designator carried as a suffix to the UIC indicating real property that is either remote from the reporting activity or is specially identified for geographic, functional, operational, or administrative reasons.
- Facility Number. The number permanently assigned to a building or structure. Each facility within the boundaries of a single general development map has a separate and unique number.
- Map Grid Number. The grid square location of each facility located within the boundaries of a general development map. Note that a special area designator may indicate that the facility is remote from the responsible activity, and there-

fore the grid numbers found in the RPI may be for a location on a different general development map than that used by the parent activity.

Category Code. A five-digit code that corresponds with the Category Code Nomenclature (CCN), which defines the use of the property. A CCN listing may be found in NAVFAC P-72.

Area/Unit of Measure. A quantitative measurement, expressed in the specified unit of measure (UM), of the area reported for one user (UIC) under one use (CCN). RPI area data usually employs square feet (SF) as a unit of measure, although square yards (SY) is occasionally used.

Other Measure/Unit of Measure. A quantity and UM for facilities that are commonly quantified in nonarea terms. Common units of measure are feet of berthing (FB), gallons (GA), barrels (BL), lineal feet (LF).

Alternate Measure/Unit of Measure. An alternate quantity and UM for facilities that are commonly quantified in nonarea terms. Common units are gallons per minute (GM), outlets (OL) and thousands of gallons per day (KG).

Since the potential for generating oily wastes is a function of the type of operations conducted, the key data element for exploitation of the RPI is the CCN identifier. Preparation of a list of CCNs that can generate oily wastes would permit a data processing extract of the entire RPI, producing a facility source listing. Correlation between RPI data elements and source identification needs are shown in Table 1, "Application of RPI Data."

TABLE 1. Application of RPI Data

RPI DATA ELEMENT	SOURCE IDENTIFICATION
CCN	Type of operation
Reporting Activity Name UIC Special Area Code Facility Number	Single source identification
Map Grid Number	Location of the operation on a general development map
Area/UM Other Measure/UM Alternate Measure/UM	Size of the operation

2) The Master Activity General Information Control (MAGIC) File

The source listing produced by the RPI extract provided a list of 19,600 sources assigned to 1,232 activities identified by name and UIC. The location of the headquarters for each activity in longitude and latitude to the nearest minute is maintained by NAVFAC in Washington, D.C., in a file called the Master Activity General Information Control (MAGIC) File. Although the longitude and latitude location is not correlated with a facility location on a general development map, it does define the geographic area in which the activity is located. This information was used for an initial sorting of activities.

The longitude and latitude data for each of the 1,232 previously identified UICs was extracted from the MAGIC File and computer-sorted into one-minute geographic increments (approximately 60 miles by 60 miles).

In establishing a geographic hierarchy, a complex was defined as a set of installations within sufficient proximity of each other to be served by a single oily waste system. Installations, in turn, contain activity sets known to have associated oily-waste/waste oil generation capability. For the purposes of use in NEPTUNE, an installation was defined as an identifiable portion of Navy real estate bounded by a perimeter fence that encompasses one or more Navy activities.

Since the NFA Data Base does not identify either installations or geographical concentrations of activities in complexes, it was necessary to develop the correlations that would permit evaluation on a regional basis, resulting in a hierarchy consisting of Facility - CCN - UIC - Installation - Complex.

Each Navy installation has an installation name or is named for the major activity present. All other activities located within the installation carry the installation name as part of their mailing address. It was possible, therefore, to use DOD Publication 4000.25-D, the DOD Activity Address Directory, Part I, as a UIC to address reference. All 1,232 activities were sorted in this manner and assigned to their address-specified installation. Over 300 installations were identified, of which approximately 90 are located in designated complexes. Many of the remaining 200 plus installations are reserve training centers scattered throughout the United States.

The initial development was for the Continental United States (CONUS) only. Since the information in the NFA file applies to the entire Navy; however, all entries relevant to the Navy-wide problem were included in the RPI extract data base. The formal solution of the Navy-wide problem would require installation definition for the non-CONUS activities and this was not completed as part of the NEPTUNE development effort.

2.3 Estimation System Overview

The NEPTUNE model contains a series of master data files, computational routines, and print routines that are manipulated by the user through an interactive software handler. The user is queried in English through a series of "prompts" requesting selection of "options." By specifying the desired option, the user is issuing commands to the model to carry out the requested function.

The data files contain extracts from the Navy Real Property Inventory (RPI), information on complex and installation heirarchy, installation map data, generalized unit factors for waste generation, costs, labor and energy. Computations are primarily based on solving polynomials of the form:

$$y = a + bx + cx^d + ex^f$$

The values of a through f are generalized coefficients that were obtained by regression analysis of data compiled or estimated for the various parameters associated with each source of waste oil and system component. For a specific application, the value of x is generated from data extracted from the RPI. Although the form of the polynomial is fixed in the software, the values of a through f and of x may be altered in the data base by the user.

An overview of the user manipulation process of the NEPTUNE model is presented in Figure 1. Each block represents a series of steps or user options that are tied to one or more of the 360 subroutines in the model.

2.4 Management System for Treatment of Oily Waste

An oily waste management system includes collection, transfer, treatment, recovery of waste oil, and disposal of the water fraction and any residual sludges. A generalized approach for characterizing system options requires conservative assumptions concerning component capabilities and logical

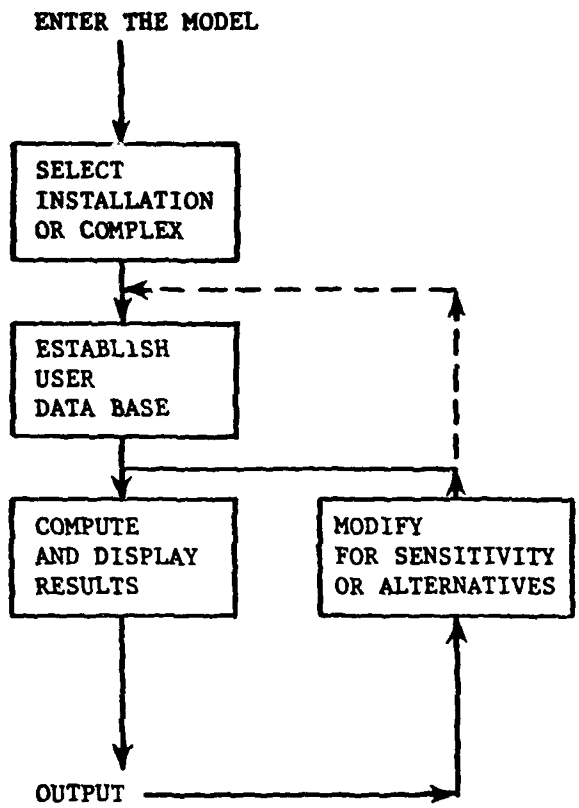


Figure 1. User manipulation of life cycle model.

component sequences. The array of system alternatives used in the model is shown in Figure 2, System Alternatives, Transfer, Treatment and Disposal of Oily Wastes.

Each building block in Figure 2 represents a function or activity that may be used in constructing a complete system. A block may contain one or more technologies and all of the support or ancillary equipment required to carry out the function. The left side of the diagram shows alternative pathways for collection and transfer of oily wastes, and treatment of the water fraction to the least stringent sewer discharge standards of 100 ppm oil content. It also includes the primary oil recovery function. The right side of the diagram covers supplemental treatment to upgrade the water fraction to meet more stringent discharge criteria, although a small amount of additional oil is recovered.

Five predetermined scenarios or pathways through Figure 1 are provided in the model, systems diagrams being given in Appendix A.

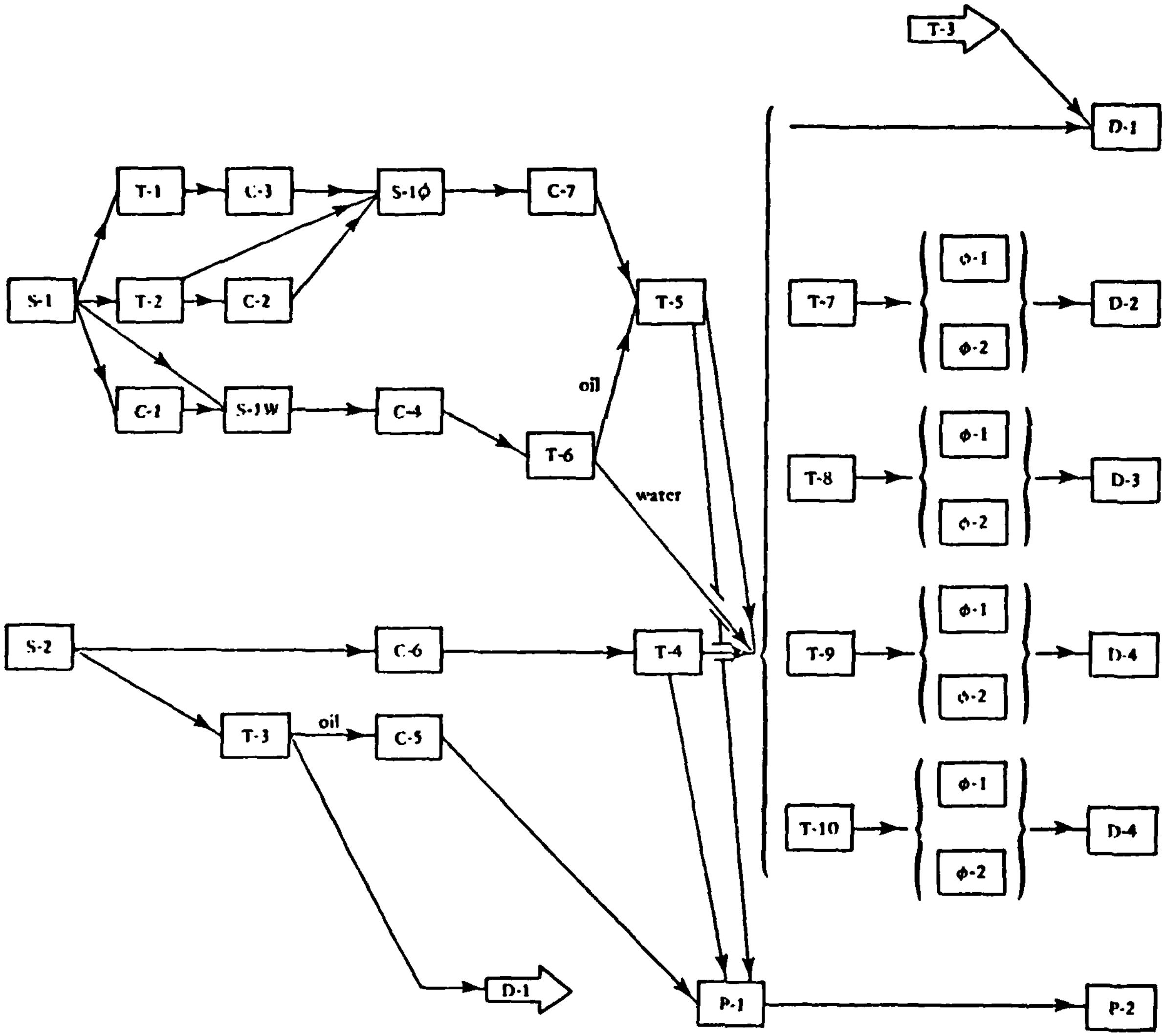
1) Baseline : Shore and ship generated oily wastes are processed at one central treatment plant in a complex. The water fraction, containing not more than 100 ppm oil, is discharged to a municipal sewer. Recovered oil is collected at one central point in the complex.

2) Alternative 1: Ship oily wastes are processed in DONUTs. Shore oily wastes are processed in separators at each source, with water fractions containing less than 100 ppm oil discharged to the sewer. Recovered oil is collected at one central point in the complex.

3) Alternative 2: Ship oily wastes are processed aboard ship, and recovered oil is transferred ashore. Shore oily wastes are processed in separators at each source, with water fractions containing less than 100 ppm oil discharged to the sewer. Recovered oil is collected at one central point in the complex.

4) Alternative 3: Ship oily wastes are transferred ashore and processed at one central treatment plant. Shore oily wastes are processed in separators at each source. Water fractions containing less than 100 ppm oil are discharged to the sewer. Recovered oil is collected at one central point in the complex.

FIGURE 2. TRANSFER, TREATMENT AND DISPOSAL OF OILY WASTES



S-1	Ship sources
S-1ϕ	Oil offloading at piers
S-1W	Wastewater offloading at piers
S-2	Shore sources
C-1	Barge ship wastes to pier
C-2	Barge ship oil to pier
C-3	Transfer donut oil to pier
C-4	Waste pipeline
C-5	Truck collection of oil
C-6	Truck collection of waste
C-7	Oil pipeline
T-1	Shipside donut
T-2	Shipboard separator
T-3	Shore source separator
T-4	Low emulsion waste to 100 ppm effluent
T-5	High emulsion oil to 100 ppm effluent
T-6	High emulsion water to 100 ppm effluent
T-7	100 ppm to 25 ppm effluent
T-8	100 ppm to 15 ppm effluent
T-9	100 ppm to 10 ppm effluent, Alt #1
T-10	100 ppm to 10 ppm effluent, Alt #2
P-1	Product oil storage
P-2	Product oil sale (value for reuse)
ϕ-1	Gravity effluent outfall
ϕ-2	Pumped effluent outfall
D-1	Sewer discharge (25 to 100 ppm)
D-2	Sewer discharge (25 ppm)
D-3	NPDES discharge (15 ppm)
D-4	NPDES discharge (10 ppm)

5) Alternative 4: Ship oily wastes are transferred ashore and processed at the nearest one of several satellite treatment plants. Shore oily wastes are processed at each source. Water fractions containing less than 100 ppm oil are discharged to the sewer. Recovered oil is collected at one central point in each satellite area.

The user must start with any one of the offered scenarios, but has the option of altering any of the components, data, or computational results to suit specific needs, local conditions, or conduct sensitivity analyses. For example, computational subroutines are provided to evaluate systems that can meet stringent sewer standards or discharge to receiving waters under various NPDES criteria. Data that can be generated by the model includes:

(1) Annual oily waste generation volume by type and source, with totals by installation and complex

(2) Potential oil recovery volume

(3) Energy requirements for system operation

(4) Labor requirements

(5) Capital, O&M, and life cycle costs of systems

2.5 Practical Use of the Model

The NEPTUNE model is loaded on a central time-sharing computer system accessible by telephone. A user must have at his disposal a terminal, acoustic coupler or modem, and a telephone. Of course, an account with the time-sharing system will also be required. A printing terminal is desireable to produce hard copy for subsequent use, although a video display terminal can be used.

The user must have the appropriate installation maps at his disposal, since certain computational routines will require the input of locations for treatment facilities, oil disposal points and wastewater disposal points. If berthing facilities are present, a berthing plan must also be entered. As described in subsequent sections of this document, all required information should be compiled in advance to reduce terminal connect time.

The model includes error messages of two types. The first type requires remedial action by the user, and will appear if map, source location or berthing data is missing. The user must correct these deficiencies, since

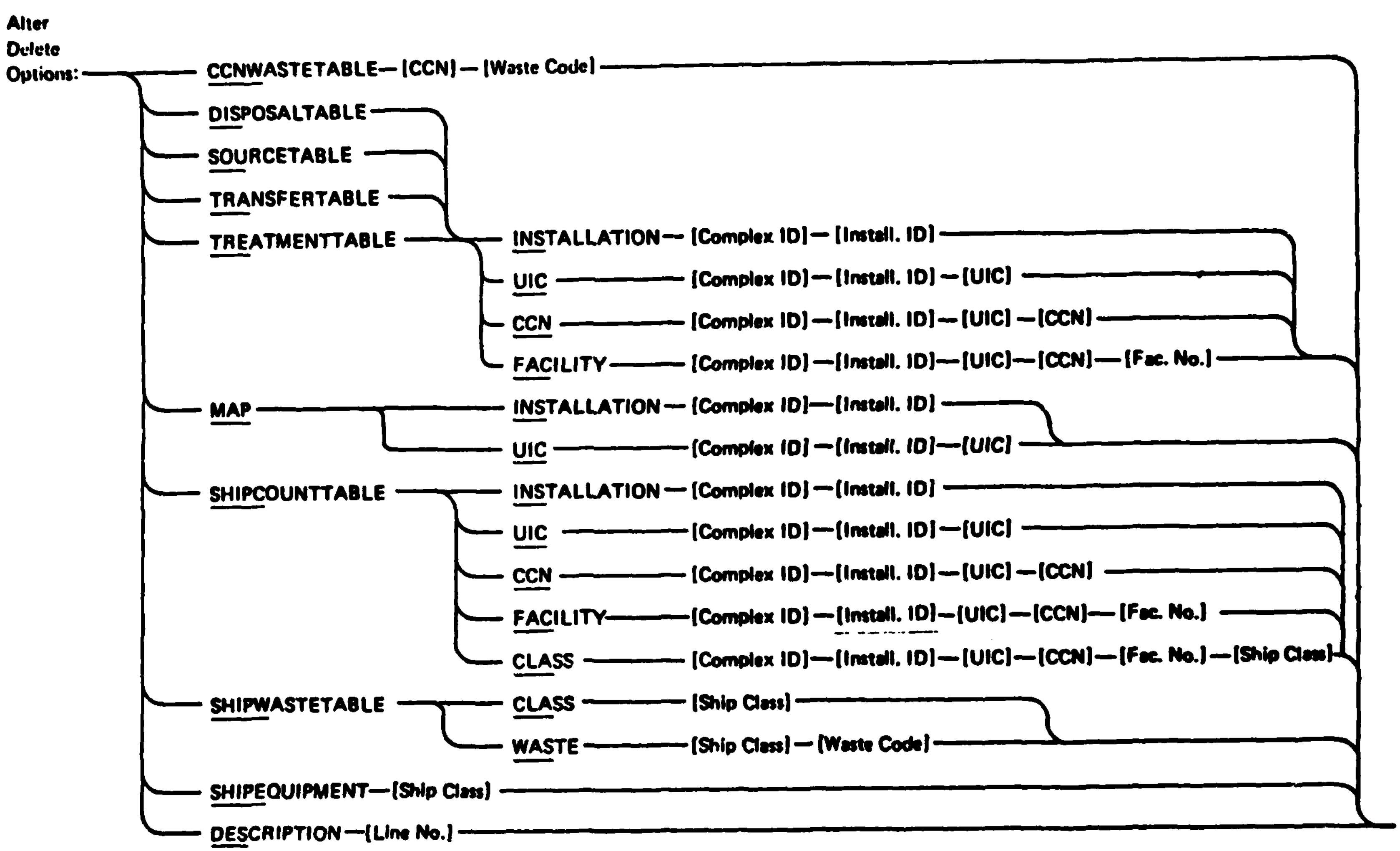
the missing or incompatible data will be required for some of the computational routines. The second type is a warning of possible error, and does not require remedial action. It is intended to alert the user that the indicated item appears to be outside reasonable limits, and may warrant checking. Generally this type of message is due to an error in the RPI extract, such as a filling station showing 10,000 "outlets" and eight square feet of floor area produced by juxtaposition of the RPI column entries. The procedures for checking and correcting errors is quite simple.

Information relevant to the estimation of the system cost components is organized into two data bases, the MASTER data base containing tables of the data sets subject to low profitability of modification and the USER data base constructed by the user (possibly by moving data from the MASTER) for his own use and manipulation. In this way, archived data needs to be stored in only one place and the user has complete flexibility for making adjustments as local conditions require.

A useful feature is the ability to limit displays to elements occurring within certain "windows" or user specified ranges. This acts as an elimination trap for results that may be based on erroneous elements, and limits output data sets to manageable levels.

The sequence of user inputs is guided by a series of "railroad" diagrams indicating various pathways of operation. A sample diagram is given in Figure 3. Not all of the keywords need to be displayed, only the underlined portions. The level of information given to the user is adapted according to the number of errors encountered or previous aid requests. In this way, a novice user is instructed as to the next action required, while the experienced user will reference the documentation or proceed from memory.

FIGURE 3. SAMPLE USER GUIDE PAGE



SECTION III

ASSESSMENTS OF NEPTUNE

3.1 General Considerations

The primary objective of such a model is to facilitate, manage and control the evaluation of cost factors for a number of alternative approaches to oily waste/waste oil collection, transfer, treatment and disposal. Since most of the information required for this purpose has already been tabulated in the master data base tables the user need only add certain local data such as berthing plans and the location of the central treatment facility.

A model of this kind can give a quick indication of the most economic overall philosophy for the complex under consideration. It is not designed for accurate costing but given its relative accuracy specifications (25%) the correct initial direction is indicated. Subsequent modification of the internal data and algorithms can refine these estimates to any desired degree.

There are a number of advantages to a computer based system of this kind. They include the following:

a) Economy of information generation and distribution - data need only be saved in one place and accessed as needed by all users.

b) Once the program is tested and accepted it considerably reduces the computation cost, the elapsed time for cost factor computation, and the risk of mistakes.

c) The data editing capabilities provide considerable flexibility to include specialized local factors and to update estimates accounting for various levels of inflation.

d) The keyword based control system provides a clear listing of the user actions and results.

3.2 Accuracy of Predictions

The model has been applied to determine source and system cost factors for the San Diego Naval complex. This complex contains virtually all of the source types likely to be met in practice and was therefore an excellent test

case. The assessments we give here are, to a large extent, based on the judgements of individuals involved in that exercise. The key members of the development and testing activity are listed in Appendix B.

There was a significant problem with the formal auditing of the NEPTUNE predictions since a complete manual checking effort might involve up to 30,000 calculations and a man year of labor. Hence only limited selective checking was possible and the validity of the model has been assessed by the total costs predicted for San Diego and the Navy-wide case.

Assessments by cognizant NAVFAC personnel revealed the following:

1) The cost estimates obtained by NEPTUNE for San Diego were approximately correct, and

2) The estimated maximum daily volume of effluent was too high.

Two causes have been identified for the second observation. Firstly, the emissions data used in the NEPTUNE model were based on data given in a NAVSEA report[3] which were conservative in that they might be somewhat larger than the true values. This was borne out in a study performed by P. A. Engineering[4] indicating smaller mean emission rates. Table 2 presents mean daily emission rates from the two studies for various ship classes. The NAVSEA data for annual emission rates were divided by 260, the number of working days in a year. (The large discrepancies for the SS classes arise from the use of an unrealistically large rate of 5000 gpd under P. A. Engineering.).

The second reason for the maximum daily volume of effluent being too high is the model procedure of computing the maximum daily flow as the sum of the individual maxima of all the sources. It is very unlikely that all sources would be emitting effluent at the maximum rate at the same time and therefore the model procedure is likely to overestimate the actual maximum emission rate. A more valid procedure would be to compute the probability distribution of the maximum from the statistics of the behaviour of individual sources and base a decision on a given small probability of exceeding the selected figure.

A key area of concern in accuracy evaluation is the validity of the regression relationships used to predict the emission rates and associated

TABLE 2.

DISTRIBUTION OF BILGE GENERATION RATES BY SHIP CLASS

Ship Class	No.	Thousands of Gallons per Day NAVSEC	Percent NAVSEC	Thousands of Gallons per Day P.A. Engineering	Percent P.A. Engineering
AD	12	129.2	1.61	60	1.82
AE	13	170.0	2.11	65	1.94
AFS	7	88.8	1.10	35	1.06
AGDS	1	5.4	0.07	5	0.15
AGFF	1	8.8	0.11	5	0.15
AGF	1	115.4	1.43	5	0.15
AGSS	1	1.0	0.01	5	0.15
AG	1	0.2	0	5	0.15
AOE	4	141.5	1.76	20	0.61
AOR	7	239.6	2.98	35	1.06
AO	9	301.2	3.75	45	1.37
ARS	9	18.0	0.22	45	1.37
AR	4	23.1	0.29	20	0.61
ASR	6	1.0	0.01	30	0.91
AS	14	280.0	3.48	70	2.31
ATF	6	0.9	0.01	30	0.91
ATS	3	5.5	0.07	15	0.46
AVM	1	7.7	0.10	5	0.15
AVT	1	180.8	2.25	5	0.15
CGN	9	58.8	0.73	45	1.37
CG	20	318.4	4.22	100	3.19
CVN	4	984.6	12.24	164	4.98
CV	10	1807.7	22.47	410	12.45
DDG	37	298.2	3.71	185	5.62
DD963	30	150.0	1.86	150	4.55
DD	41	346.9	4.31	205	6.22
FFG1	6	46.2	0.57	30	0.91
FFG7	10	46.2	0.57	50	1.52
FF	58	513.3	6.38	290	8.80
LCC	2	65.4	0.81	10	0.30
LHA	5	173.1	2.15	25	0.76
LKA	6	203.1	2.53	30	0.91
LPA	1	19.2	0.24	10	0.30
LPD	14	468.4	5.82	70	2.13
LPH	7	234.2	2.91	35	1.06
LSD	13	140.1	1.74	65	1.97
LST	20	338.6	4.21	100	3.04
MSO	25	3.0	0.04	125	3.79
PG	2	0.3	0	10	0.30
PHM	2	0.0	0	10	0.30
SSBM	43	33.6	0.41	215	6.53
SSN	82	47.6	0.59	410	12.45
SS	1	8.0	0.10	40	1.21

cost factors. As mentioned earlier, the general form of the equation used for prediction is:

$$y = a + bx + cx^d + ex^f \quad (1)$$

where y is the quantity to be estimated, x is a parameter available from the RPI and a through f are constant coefficients. In practice the equation used is never as complicated as equation (1), with some or most of the terms being dropped. For example, the use of the coefficient, a, alone would imply a constant value for the estimated quantity y. Also, practical formulae derived from physical principles and/or engineering experience were written down as subsets of equation (1).

The most common forms of equation (1) used in curve fitting sampled data were:

$$y = a + bx \quad (2)$$

and, $$y = cx^d \quad (3)$$

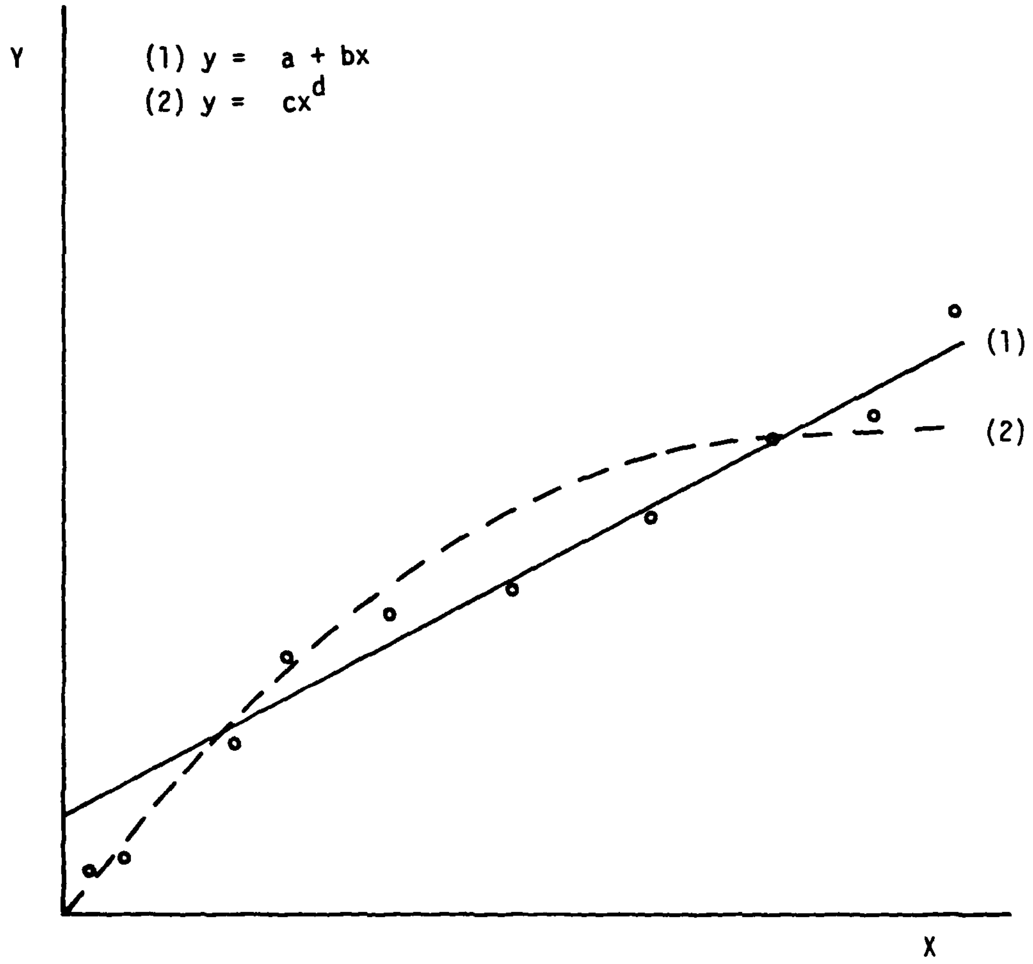
Equation (2) is already in linear form and therefore amenable to the direct application of a linear least squares fitting procedure while equation (3) is converted to linear form by taking the logarithms of both sides:

$$\ln y = \ln c + d \ln x \quad (4)$$

The standard Hewlett-Packard library routines for fitting data actually use equations (2) and (4) for estimating the coefficients a, b, c, and d with unit weight (or a constant error) assigned to each point.

This action has an important effect in that the impact of errors in the input data will depend on the type of equation being used to perform the fit. If equation (2) is used then the error in y for each point is assumed to be a constant while, if equation (3) is used, the error in ln y is assumed to be a constant. This is equivalent to assuming a constant percentage error in y. Thus, if equation(3) is used, the fit will tend to favor the smaller values of y, while, if equation (2) is used, the residuals (i.e. the difference between the time value and fitted value) will be uniform across the plot. This is illustrated in figure 4 where we have plotted the results of curve fits using equations(2) and (3) to a representative data set. It can be seen that while equation (3) (dashed line) was very successful in representing the smaller

FIGURE 4. COMPARISON OF LEAST SQUARES FIT USING DIFFERENT FUNCTIONAL FORMS



values of y, it was inferior to equation (2) in fitting the larger y values.

The procedure that is required to resolve this discrepancy involves the use of a slightly more sophisticated curve fitting package, and the *a priori* determination of the weights of the input points. If the weights of the points are input then appropriate adjustments can be made when changing functional forms such as the transformation from equation (2) to equation (3).

The establishing of an *a priori* weight involves two considerations:

1) The estimated likely error in the appropriate y value, and

2) The likely frequency of x values in the range of the current value.

If the likely error is high then the weight should be lower, while if the frequency of corresponding samples in the case being treated is high then the weight should be higher. This, of course, leads to a situation where different coefficients may arise for the estimations of costs and/or volumes for different cases. While this may be necessary in some cases, it is to be hoped that the formulae can be derived with broad applicability.

The ultimate goal of the weighting procedure is to minimize the error in the end result. This optimization can be performed either at the local level (i.e. facility, U. I. C., installation, complex) or on a Navy-wide basis. The decision as to the degree of localization required can only be made properly after a formal error analysis is complete. This was not done in the development of the NEPTUNE system. As a result it is likely that improvements can be accomplished by limiting the populations employed in the regression coefficient determinations.

A further problem arising from the omission of a complete error analysis is that we do not know the covariance matrix of the derived coefficients and are therefore unable to compute the standard error of our estimate even if the sampled population is known to be truly representative. Information regarding the goodness of fit would be valuable in identifying the key areas of uncertainty in the cost estimates and highlighting those areas where localization may be valuable in the parametric description.

If the NEPTUNE code is to be applied in the design domain then there would be advantages to incorporating regression fitting routines to estimate

locally valid parameters from locally sampled data. This would allow the basic philosophy of the NEPTUNE system to be retained while permitting a formal reduction based on locally determined parameters.

3.3 Practical Usage Considerations

The principal judgements in this section are based on a review of the program documentation, some practical testing and recorded observations of users of the program.[3] There are two levels of possible usage:

1) Estimations made with minimal user input (perhaps berthing plan and control treatment site location only).

2) Design related estimations involving editing to accommodate local factors.

The training requirements for usage level (1) are minimal. One or two hours of instruction should be adequate to orient the user to the terminal protocols. As stated in the user documentation, development maps and a berthing place are the immediate requirements. The user, will, after a little practice employ the railroad diagrams of the documentation or even proceed from memory. While the system does not claim to be entirely foolproof its self-prompting modes are helpful in eliminating errors, and the windowing feature can be used to trap erroneous data entries in the RPI or user input data. The degree and level of prompting is tailored to the user's experience; the program "learns" how much detail to give as it proceeds.

The map data base allows the user to enter location coordinates as marked on the map of interest and conversion to a universal scheme (latitude and longitude) is automatic. Thus, mixed coordinate schemes are allowed with minimal applications danger.

In performing estimations for complexes outside of CONUS, there may be problems with the assignments of installations to various sources. Thus the referencing hierarchy can break down. The formal solution to this problem requires the completion of installation assignment to all oily waste sources indicated by searching the RPI. Some problems associated with "special area" codes may require detailed attention.

The use of NEPTUNE in design mode requires selective editing of NEPTUNE data bases from a knowledge of local features. At this level, the training required for system orientation would be the same as for level (1), but the user would probably improve his efficiency considerably with practice, as he becomes familiar with the program commands for implementing the required changes. It is estimated that one week of practice would enable cognizant Engineering Field Division personnel to become proficient in exploiting NEPTUNE features at this level.

The editing features within NEPTUNE allow any or all of the computed parameters to be modified by the user. This provides considerable flexibility for adjusting the model procedures. Compensations for the cost of transportation systems over various types of terrain can readily be made and the impact of any special source type can be accommodated. The fitting of locally sampled data to a representative form is not currently possible, however, and this would offer the possibility of enhancing the accuracy of local estimates.

The NEPTUNE estimating procedure offers a radical departure from existing practices. The onus, therefore, in demonstrating compatability with existing procedures resides in the comparison of the application of NEPTUNE with existing conventional methods. The editing capability, once again, provides a key link in that estimates can be adjusted according to the results of conventional methods where those methods have proven reliability. It will be only when NEPTUNE has operated successfully on a large number of cases that the weights of the estimates can be raised when compared with the conventional procedures.

3.4 Ancilliary Information Products

While the primary goal of NEPTUNE is to produce life-cycle cost estimates for oily waste/waste oil treatment, it also provides useful clues concerning the locations of potential oily waste sources. A user who wishes to know only the identity of sources of a certain type within a certain region need only query the system for those complexes within the region of interest.

The "display table" operation of NEPTUNE allows the display of information in the MASTER and USER data bases. In this wav the user can recall the factors that are critical to any estimate and identify factors which should be edited for improved local estimation.

Since the information for source location and effluent volume all reside within the EDP environment both on-line and off-line processing programs can be added to the package to perform such tasks as:

1) Determining the geographical distribution of individual sources,

2) Determining the geographical distribution of oily waste generation volume, or

3) Determining an estimate of the center of mass of the oily waste generation for aiding treatment plant site selection.

SECTION IV

ESTIMATES FOR THE NAVY-WIDE CASE BASED ON NEPTUNE

While the Real Property Inventory contains data on a Navy-wide scale, the practical application of NEPTUNE to this case was not possible for two reasons:

1) Excessive computer resources would be required

2) Installation descriptions for the Navy-wide case were incomplete.

It was therefore necessary to extrapolate to the Navy-wide case based on the results of the San Diego survey.

Two methods of extrapolation were tried. That of the present work was based on the observation that the bilge contributed a very large fraction (over 99 percent) of the total budget. Thus it seemed reasonable to extrapolate costs on the basis of the bilge content alone using the homeport descriptions[5] to construct the berthing plans. The second method involved the application of weighting factors to various components of the San Diego results according to the ratio of the Navy-wide situation to the San Diego component.[6]

In using the bilge generation rate for extrapolation from San Diego we encountered some difficulties in that the latest data on emissions[4] indicated rates substantially lower than those incorporated in the NEPTUNE code. Also the berthing plan contained fewer ships than those home-ported in San Diego. However, since the program has been judged to produce a result that was approximately correct, we elected to proceed with both the given berthing plan and the NAVSEA data.

This procedure developed a daily bilge generation rate estimate of 1.30 million gallons per day while the Navy-wide rate was 8.04 million gallons per day (as compared with 3.34 million gallons per day from the P.A. Engineering data). We then applied a cost multiplying factor of $\frac{8.04}{1.30}$ to all the San Diego cost factors to estimate the Navy-wide cost for the BASELINE case, i.e. centralized treatment.

For the analysis of ALT2, the shipboard treatment case, we attempted to take ship size distribution into account. Using the NAVSEC emissions data we estimated the mean daily emission per ship to be 23.1 thousand gallons for San Diego while the Navy-wide number was only 14.4 thousand gallons. In other words, San Diego is homeport to ships generating an average 60% more than the average ship in the Navy. We would therefore have to capitalize and maintain 60% more shipboard treatment plants per gallon of oily waste than at San Diego. Thus, to estimate the Navy-wide cost estimates we used a factor of $1.6 \times \frac{8.04}{1.30}$ as the multiplier of San Diego costs.

The results for the estimates are given in Table 3 for the two approaches of (1)C. Arnold and (2) the present study under the categories of capital cost (C), annual operation and maintenance cost (O + M) and annualized life cycle cost (LCC). The costs are all expressed in millions of dollars. The LCC estimates for the BASELINE case differed by 20 percent while those for the shipboard separators agreed to within 3 percent.

At first sight these results tend to support the shipboard treatment system. It must be remembered, however, that labor costs have been excluded from the shipboard case. Further, a review of the details of the BASELINE result for San Diego indicated that the majority of the LCC (more than 85%) was associated with the required transportation network. Therefore, it is likely that a somewhat decentralized treatment concept would provide significantly smaller cost estimates.

TABLE 3

NAVY-WIDE COST ESTIMATES FOR OILY-WASTE/WASTE OIL COLLECTION, TRANSFER TREATMENT AND DISPOAL (MILLIONS OF DOLLARS)

METHODS OF ESTIMATION

1. Application of cost multipliers to NEPTUNE estimates for San Diego and subsets thereof (C. Arnold).

2. Use of NEPTUNE estimates for San Diego with multiplying factor based on total daily bilge generation rates. Factor = $\frac{8040}{1296}$ = 6.206. 60% added to shipboard separator costs to account for scale related efficiency loss.

ESTIMATION	BASELINE			SHIPBOARD SEPARATORS		
METHOD	C	O+M	LCC	C	O+M	LCC
1	196.27	16.3	45.45	160.1	6.19	31.84
2	179.48	11.0	38.85	172.58	4.18	30.77

SECTION V

CONCLUSIONS

The program NEPTUNE does meet its stated goals of 25 percent relative accuracy with built-in flexibility and links to current procedures through the editing modes. It is friendly to users and the training requirements are minimal. Additionally, the program readily identifies oily waste sources as a guideline for any systematic search.

The principal limitations lie in the area of error analysis and propagation. The user does not know anything about the potential errors in the cost estimates he obtains. A major recommendation of this report is therefore to complete an error analysis and incorporate its results into the model. With this new information we can decide whether a global Navy-wide fit is acceptable. If not, we would then have some judgement criteria for assessing the merits of different subset selection schemes.

The procedure used to determine the regression relationships ignored the issue of the weight of the points. In some cases, therefore, the smaller values of cost or effluent volume were fitted better while in other cases the larger values were fitted better. The correct procedure would be to assign *a priori* weights to the data according to their anticipated frequency in the estimation case description.

There would be advantages also to allowing a regression within the model over user input statistics to permit local best fits to be obtained. This would contribute towards expanding the possible applications of the program and to derivatives into the design phases.

We have analyzed oily waste sources and determined that bilge dominates the effluent volume, contributing more than 99 percent of the total. We have made two estimates of the Navy-wide bilge generation rate and determined values of 3.34 and 8.04 million gallons per day using P. A. Engineering and NAVSEC data respectively. The former figure is probably more accurate as it is derived from more recent data.

Using bilge volume as a basis we computed life-cycle cost estimates of 45.45 million dollars per year and 31.84 million dollars per year for the centralized and shipboard treatments respectively. The corresponding figures obtained by another worker using independent weights were 38.85 and 30.77 million dollars per year. After reviewing the surrounding factors, however, we are unable to establish a significant cost savings in the shipboard system.

APPENDIX A

SYSTEM DESCRIPTIONS FOR BASELINE AND ALTERNATIVES

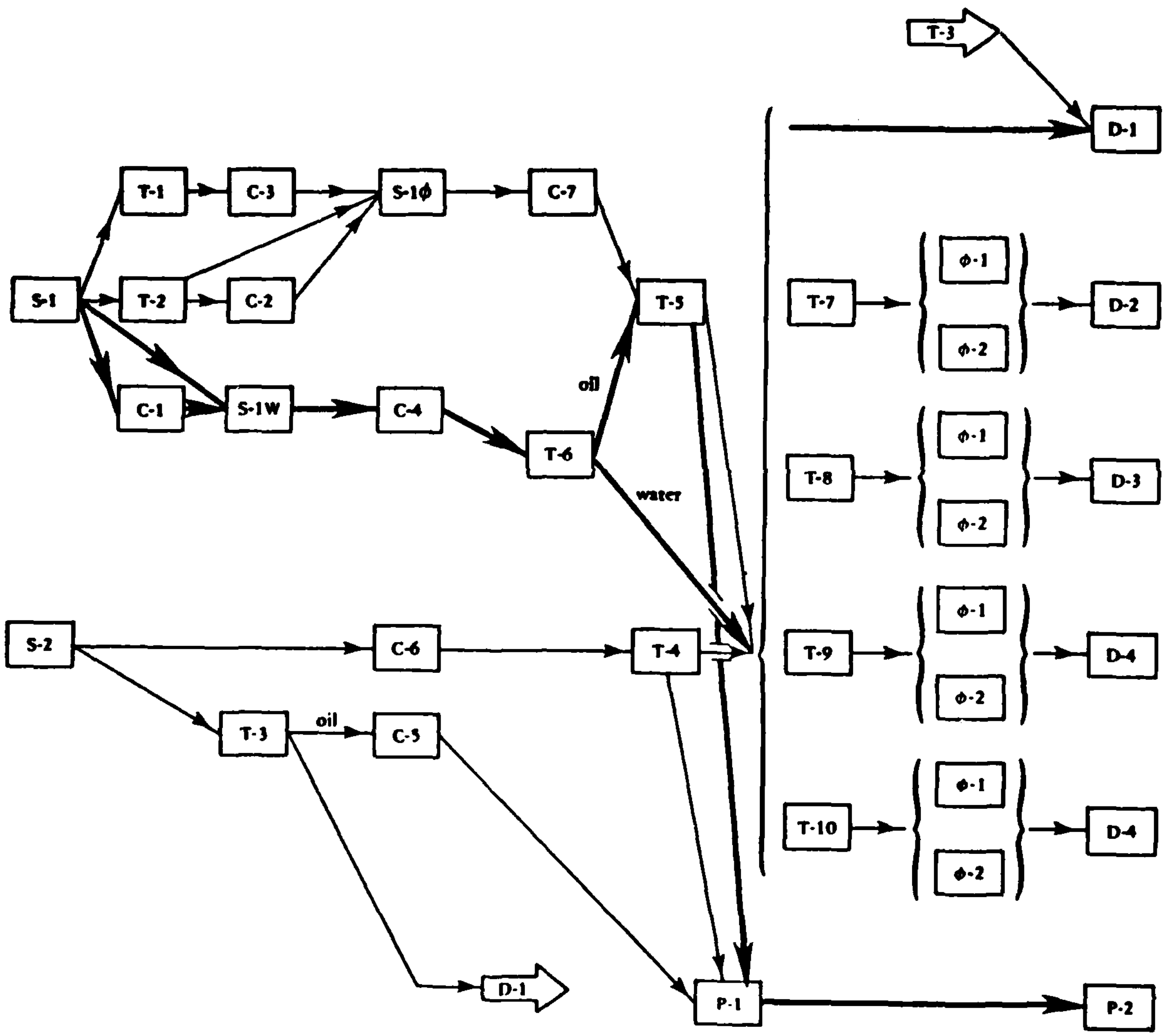
THE BASELINE SYSTEM

Central Treatment

Conceptually, any Navy complex can be served by one centrally located treatment facility to which all oily wastes generated within the complex are transferred. This configuration has been selected as the Baseline System, with the following assumptions completing the general scenario:

- Ship wastes will be transferred by pumped pipeline from foot of pier locations
- Shore wastes will be collected and transferred by truck
- Treatment will produce an effluent containing less than 100 ppm oil
- Effluent will be discharged to a municipal sewer system
- Recovered oil will be sold or used as a boiler fuel having a value equivalent to its sale value

The Baseline System is shown graphically in Figure A-1.



S-1	Ship sources
S-1φ	Oil offloading at piers
S-1W	Wastewater offloading at piers
S-2	Shore sources
C-1	Barge ship wastes to pier
C-2	Barge ship oil to pier
C-3	Transfer donut oil to pier
C-4	Waste pipeline
C-5	Truck collection of oil
C-6	Truck collection of waste
C-7	Oil pipeline
T-1	Shipside donut
T-2	Shipboard separator
T-3	Shore source separator
T-4	Low emulsion waste to 100 ppm effluent
T-5	High emulsion oil to 100 ppm effluent
T-6	High emulsion water to 100 ppm effluent
T-7	100 ppm to 25 ppm effluent
T-8	100 ppm to 15 ppm effluent
T-9	100 ppm to 10 ppm effluent, Alt #1
T-10	100 ppm to 10 ppm effluent, Alt #2
P-1	Product oil storage
P-2	Product oil sale (value for reuse)
φ-1	Gravity effluent outfall
φ-2	Pumped effluent outfall
D-1	Sewer discharge (25 to 100 ppm)
D-2	Sewer discharge (25 ppm)
D-3	NPDES discharge (15 ppm)
D-4	NPDES discharge (10 ppm)

FIGURE A-1. BASELINE SYSTEM
TRANSFER, TREATMENT AND DISPOSAL OF OILY WASTES

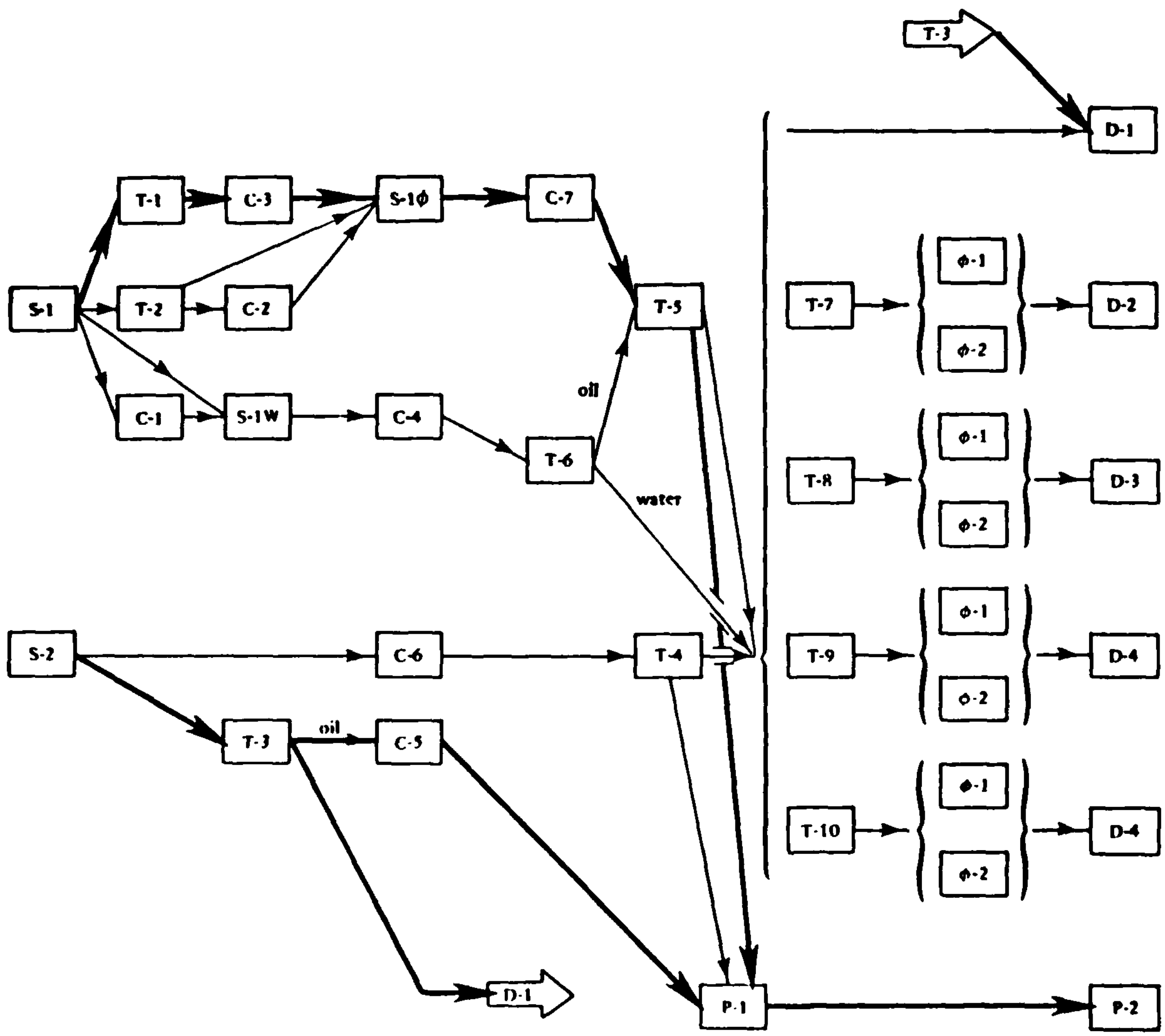
ALTERNATIVE SYSTEM 1

Source Treatment and Shipside DONUTs

DONUT systems are currently used for in-situ treatment of ship bilge wastes, and their inclusion in this alternative permits comparison of current operations with future systems. The Alternative 1 scenario incorporates the following assumptions:

- Shipside DONUT systems with recovered oil transferred ashore via LCM (Mike Boat)
- Pumped oil pipeline from the piers to the oil disposal point
- API or parallel plate type separators at each shore source with effluent discharged to the sewer system
- Truck collection and transfer of the oil fraction from the shore source separators to the oil disposal point
- Recovered oil sold or used as a boiler fuel leaving a value equivalent to sale

Alternative System 1 is shown graphically in Figure A-2.



S-1	Ship sources
S-1Φ	Oil offloading at piers
S-1W	Wastewater offloading at piers
S-2	Shore sources
C-1	Barge ship wastes to pier
C-2	Barge ship oil to pier
C-3	Transfer donut oil to pier
C-4	Waste pipeline
C-5	Truck collection of oil
C-6	Truck collection of waste
C-7	Oil pipeline
T-1	Shipside donut
T-2	Shipboard separator
T-3	Shore source separator
T-4	Low emulsion waste to 100 ppm effluent
T-5	High emulsion oil to 100 ppm effluent
T-6	High emulsion water to 100 ppm effluent
T-7	100 ppm to 25 ppm effluent
T-8	100 ppm to 15 ppm effluent
T-9	100 ppm to 10 ppm effluent, Alt #1
T-10	100 ppm to 10 ppm effluent, Alt #2
P-1	Product oil storage
P-2	Product oil sale (value for reuse)
Φ-1	Gravity effluent outfall
Φ-2	Pumped effluent outfall
D-1	Sewer discharge (25 to 100 ppm)
D-2	Sewer discharge (25 ppm)
D-3	NPDES discharge (15 ppm)
D-4	NPDES discharge (10 ppm)

FIGURE A-2. ALTERNATIVE SYSTEM NO. 1

TRANSFER, TREATMENT AND DISPOSAL OF OILY WASTES

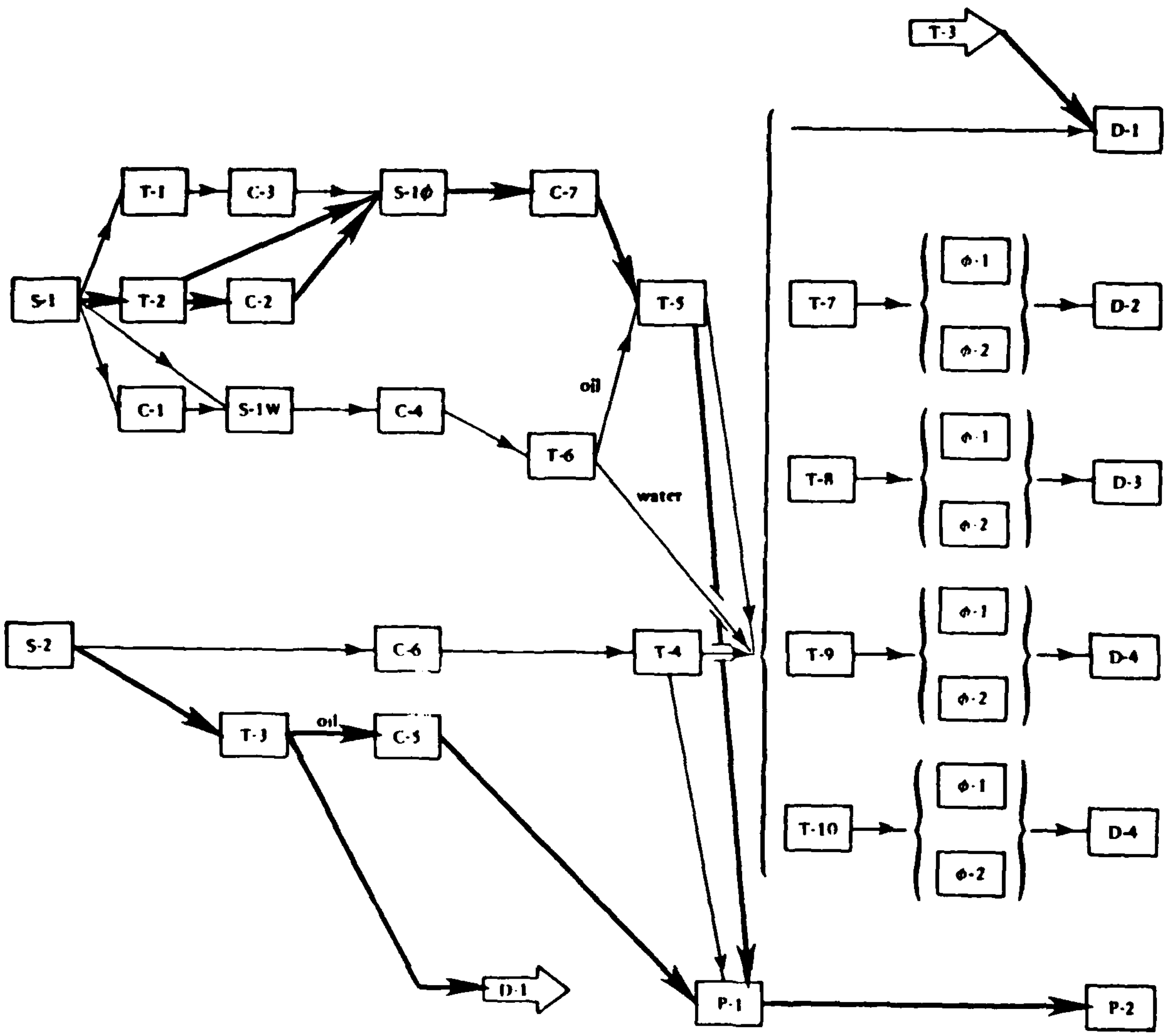
ALTERNATIVE SYSTEM 2

Source Treatment and Shipboard Treatment

Some Navy ships have been fitted out with shipboard separators, and the entire fleet may ultimately receive such equipment. Shipboard treatment combined with shore source treatment represents the opposite end of the system spectrum from the baseline central treatment system. The Alternative 2 scenario is based on the following assumptions:

- Shipboard treatment with effluent discharged overboard and recovered oil held for transfer ashore
- Ship discharge of oil directly to pier risers or to piers via waste oil barges
- Transfer of oil from piers to the oil disposal point in pumped pipelines
- API or parallel plate type separators at each shore source with effluent discharged to the sewer system
- Truck collection and transfer of the oil fraction from the shore source separators to the oil disposal point
- Recovered oil sold or used as a boiler fuel having a value equivalent to sale

Alternative System 2 is shown in Figure A-3.



S-1	Ship sources
S-1ϕ	Oil offloading at piers
S-1W	Wastewater offloading at piers
S-2	Shore sources
C-1	Barge ship wastes to pier
C-2	Barge ship oil to pier
C-3	Transfer donut oil to pier
C-4	Waste pipeline
C-5	Truck collection of oil
C-6	Truck collection of waste
C-7	Oil pipeline
T-1	Shipside donut
T-2	Shipboard separator
T-3	Shore source separator
T-4	Low emulsion waste to 100 ppm effluent
T-5	High emulsion oil to 100 ppm effluent
T-6	High emulsion water to 100 ppm effluent
T-7	100 ppm to 25 ppm effluent
T-8	100 ppm to 15 ppm effluent
T-9	100 ppm to 10 ppm effluent, Alt #1
T-10	100 ppm to 10 ppm effluent, Alt #2
P-1	Product oil storage
P-2	Product oil sale (value for reuse)
ϕ-1	Gravity effluent outfall
ϕ-2	Pumped effluent outfall
D-1	Sewer discharge (25 to 100 ppm)
D-2	Sewer discharge (25 ppm)
D-3	NPDES discharge (15 ppm)
D-4	NPDES discharge (10 ppm)

FIGURE A-3. ALTERNATIVE SYSTEM NO. 2

TRANSFER, TREATMENT AND DISPOSAL OF OILY WASTES

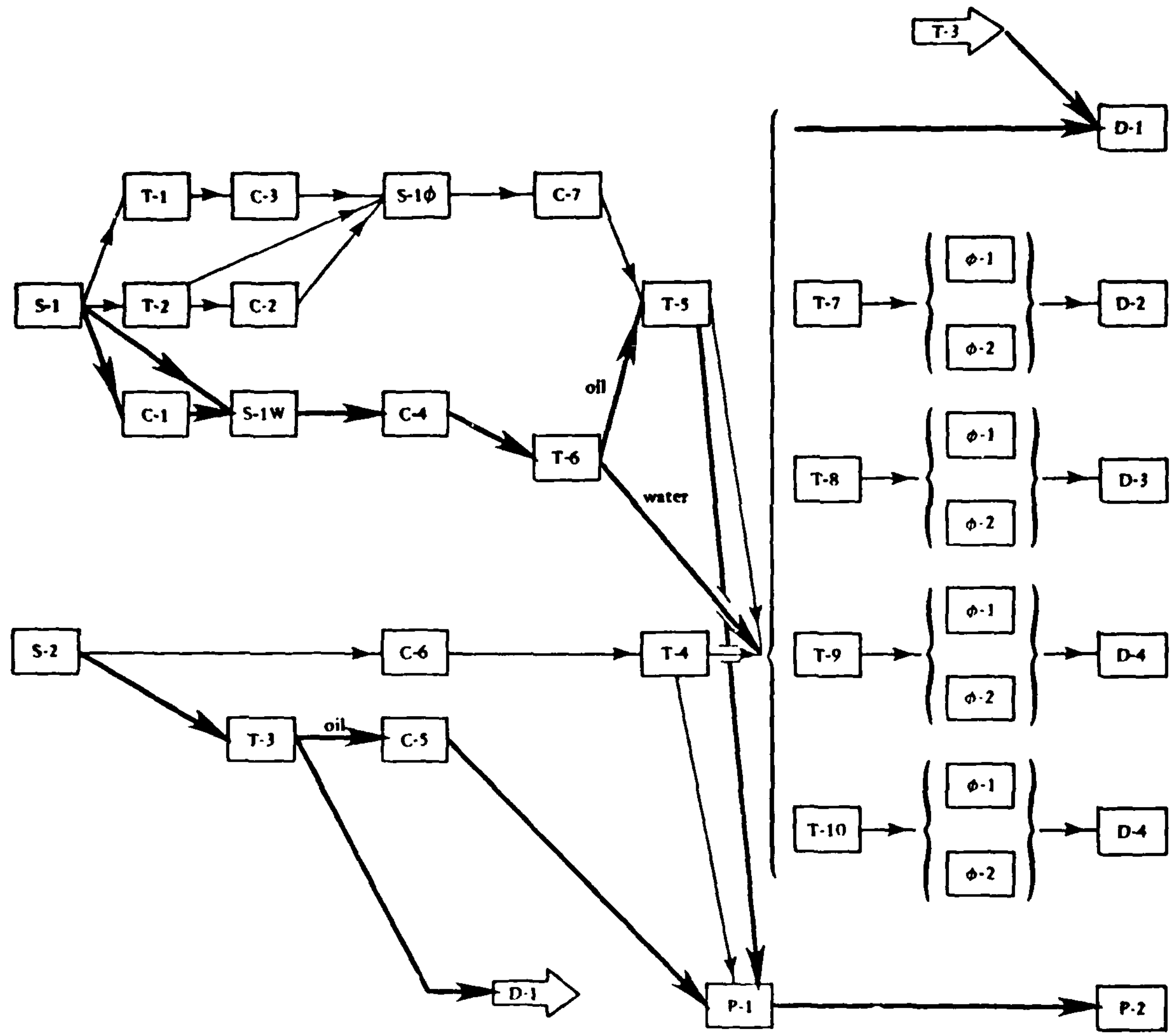
ALTERNATIVE SYSTEM 3

Central Treatment of Ship Waste and Source Treatment of Shore Wastes

Ship wastes transferred ashore apparently represent the majority of oily wastes received at shore activities. In addition, bilge wastes may be saline and highly emulsified, requiring somewhat different treatment than the smaller volumes generated at shore facilities. Alternative System 3 addresses these possibilities and is defined by:

- Shipwastes transferred via pier risers to pumped pipelines at foot of pier locations
- Central treatment of shipwastes producing an effluent containing less than 100 ppm oil
- Effluent discharged to a municipal sewer system
- API or parallel plate type separators at each source producing an effluent containing less than 100 ppm oil for discharge into the sewer
- Truck collection and transfer of the oil fraction from shore source separators to the oil disposal point
- Recovered oil sold or used as a boiler fuel having a value equivalent to sale

Alternative System 3 is shown in Figure A-4.



S-1	Ship sources
S-1ϕ	Oil offloading at piers
S-1W	Wastewater offloading at piers
S-2	Shore sources
C-1	Barge ship wastes to pier
C-2	Barge ship oil to pier
C-3	Transfer donut oil to pier
C-4	Waste pipeline
C-5	Truck collection of oil
C-6	Truck collection of waste
C-7	Oil pipeline
T-1	Shipside donut
T-2	Shipboard separator
T-3	Shore source separator
T-4	Low emulsion waste to 100 ppm effluent
T-5	High emulsion oil to 100 ppm effluent
T-6	High emulsion water to 100 ppm effluent
T-7	100 ppm to 25 ppm effluent
T-8	100 ppm to 15 ppm effluent
T-9	100 ppm to 10 ppm effluent, Alt #1
T-10	100 ppm to 10 ppm effluent, Alt #2
P-1	Product oil storage
P-2	Product oil sale (value for reuse)
ϕ-1	Gravity effluent outfall
ϕ-2	Pumped effluent outfall
D-1	Sewer discharge (29 to 100 ppm)
D-2	Sewer discharge (25 ppm)
D-3	NPDES discharge (15 ppm)
D-4	NPDES discharge (10 ppm)

FIGURE A-4. ALTERNATIVE SYSTEM NO. 3

TRANSFER, TREATMENT AND DISPOSAL OF OILY WASTES

ALTERNATIVE SYSTEM 4

Satellite Treatment of Ship Wastes and Source Treatment of Shore Wastes

Conceptually, source treatment for shore operations may be realistic, but transfer of ship-generated wastes to one central plant for treatment is not feasible due to geographic obstacles such as a bay or river. Shoreside treatment of ship-generated wastes can be accomplished at two or more shore-based plants where each plant serves a geographic portion of the complex. This alternative allows for such satellite plants. Assumptions that apply to each satellite system are identical to those previously defined for Alternative System 3, and Figure A-4 will apply.

APPENDIX B

COGNIZANT PERSONNEL

COGNIZANT PERSONNEL

NAME	ORGANIZATION	AREA OF INTEREST
Charles Imel	CEL (805) 982-4191	Chief, Environmental Protection Branch.
Jay Crane	CEL	Monitor, NEPTUNE development contract.
Adolph Bialecki	CEL	Civil Engineer, Treatment systems technology.
Bob Ringo	ATAC (408) 738-8200	Wrote NEPTUNE Code .
Jay Zwisler	ATAC	" " "
Joe Lawrence	ATAC (805) 488-1213	Derived emissions rates formulae.
Joe Moran	Epoch Engineering (415) 825-0595	Surveyed emissions to generate data for regressions. Tested source validity.
Clyde Arnold	O. S. U.	Used NEPTUNE to generate Navy-wide cost estimates based on application of multiplying factors to San Diego results.
Norm Schmockel	NAVFAC West Division	Exercised NEPTUNE during San Diego test case. Potential user.
Steve Ehert	NESO (805) 982-4949	Potential user. Joined development review meetings.
Sol Schwartz	P. A. Engineering (415) 924-8587	Supervised project to reevaluate emissions rates.

APPENDIX C

DISTRIBUTION OF SHIPS AND BILGE GENERATION VOLUME
BY HOMEPORT AND SHIP CLASS

SHIP COUNT BY HOME PORT AND SHIP CLASS

SHIP CLASS	SAN DIEGO	NORFOLK	YOKO-SUKA	GAETA	CHARLES-TON	MAY-PORT	PEARL HARBOR	BREM-ERTON	ALAMETA	PORT-LAND,OR	NEW ORLEANS	SEATTLE	LONG BEACH	PHILA-DELPHIA	TAMPA	SAN FRANCISCO
AD	3	3			1	1	1									
AE																
AFS		3	1						2							
AGDS	1															
AGFF		1														
AGF		1														
AGSS																
AG					1											
AOE		2						2								
AOR		2														4
AO		3					3									
ARS							5									
AR	2	1														1
ASR	2	2			1											
AS	2	1			2								1			
ATF	1					1										
ATS							2									
AVM																
AVT																
CGN	3	5														
CG	9	2	2	1	3		1	1								
CVN		2						1								
CV	3	3	1			2			1							
DDG	9	9	1		5	3	6						1	3		
DD963	7	8			1								2			
DD	2	2			4	4	2			2	1	2	4	4	1	1
FFG1	3	1			1	1										
FFG7						1										
FF	14	4	4		8	6	9			1		2		2		
LCC	1	1														
LHA	2	1														
LPA		1											1			
LPD	6	7											1			
LPH	3	4														
LSD	7															
LST	8												1			1
MSO	2				4	1						2	2			2
PG																
PHM	1															
SSBN					16		10									
SSN	12	13			7		12	1								
SS	3						1	1						1		
LKA	3	2														1
TOTAL	109	84	9	1	54	20	52	6	3	3	1	6	13	10	1	10

SHIP COUNT BY HOME PORT AND SHIP CLASS

SHIP CLASS	LITTLE CREEK	PERTH AMBOY	ST.PETERS-BURG	PORT-LAND,ME	PANAMA CITY	W.S. EARLE	CONCORD	OAKLAND	WS CHAR-LENE	LA MAD-ELLENA	GUAM	HOLY LOCH	ROTA	EVERETT	PT. HEU-NEME	NUL
AD																3
AE						2	8		2							
AFS								1								
AGDS																
AGFF																
AGF																
AGSS																
AG																
ADE																
ADR																
AO																3
ARS	4															
AR																
ASR																
AS										1	1	1	1			3
ATF	2													1	1	
ATS	1															
AVM															1	
AVT																
CGN																1
CG																1
CVN																1
CV																
DDG																
DD963																12
DD																
FFG1																
FFG7																9
FF																
LCC																
LHA																2
LPA																
LPD																
LPH																
LSD	6															
LST	10															
MSO	2	1	2	2	1											
PG	2															
PHM																1
SSBN																2
SSN																10
SS																
LKA																
TOTAL	27	1	2	2	1	2	8	1	2	1	1	1	1	1	2	48

SHIP COUNT BY HOMEPORT AND SHIP CLASS

SHIP CLASS	PENSA-COLA	NEW YORK	NEW LONDON	BAYONNE	NEWPORT R.I.	BALTI-MORE	BROOKLYN	TACOMA	BOSTON	BATH	GROTON	SUBIC BAY	VALLEJO	PASCA-GOULA	PORTS N.H.	NEWPORT NEWS
AD																
AE							1									
AFS																
AGDS																
AGFF																
AGF																
AGSS													1			
AG																
AOE																
AOR							1									
AO																
ARS																
AR																
ASR									1							
AS			1													
ATF																
ATS																
AVM																
AVT	1															
CGN																
CG																
CVN																
CV																
DDG																
DD963																
DD	1	1	1	1	4	1	1	1	1							
FFG1																
FF67																
FF					1	1			4	2						
LCC																
LHA																
LPA																
LPD																
LPH																
LSD																
LST																
MSO					2			1							1	
PC																
PHM																
SSBN											11				3	1
SSN			8								12		6	1		
SS											1	1				
LKA																
TOTAL	2	1	10	1	7	2	3	2	6	2	24	1	7	1	4	1

AVERAGE DAILY BILGE WASTE USING NAVSEA DATA (BY HOMEPORT AND SHIP CLASS) IN THOUSANDS OF GALLONS

SHIP CLASS	PENSA-COLA	NEW YORK	NEW LONDON	BAY-ONNE	NEWPORT RI	BALTI-MORE	BROOK-LYN	TACOMA	BOSTON	BATH	GROTON	SUBIC BAY	VALLE-JO	PASCA-GOULA	PORTS, NH	NEWPORT NEWS
AD																
AE							13.08									
AFS																
AGDS																
AGFF																
AGF																
AGSS													0			
AG																
AOE																
AOR							34.23									
AO																
ARS																
AR																
ASR									0.17							
AS			70.0													
ATF																
ATS																
AVM																
AVT	180.8															
CGN																
CG																
CVN																
CV																
DDG																
DD963																
DD	8.46	8.46	8.46	8.46	33.84	8.46	8.46	8.46	8.46							
FFG1																
FFG7																
FF					8.85	8.85			35.4	17.7						
LCC																
LHA																
LPA																
LPD																
LPH																
LSD																
LST																
MSO					0.24			0.12							0.12	
PC																
PHM																
SSBN											8.47				2.31	0.77
SSN			4.64								6.96		3.48	0.58		
SS											1.0	1.0				
LKA																
TOTAL	189.26	8.46	83.1	8.46	42.93	17.[illegible]	55.77	8.58	44.03	17.7	16.43	1.0	3.48	0.58	2.43	0.77

AVERAGE DAILY BILGE WASTE USING NAVSEA DATA (BY HOMEPORT AND SHIP CLASS) IN THOUSAND OF GALLONS

SHIP CLASS	SAN DIEGO	NOR-FOLK	YOKO-SUKA	GAETA	CHARLES-TON	MAYPORT	PEARL HARBOR	BREM-ERTON	ALA-MEDA	PORT-LAND OR	NEW ORLEANS	SEATTLE	LONG BEACH	PHILA-DELPHIA	TAMPA	SAN FRANCISCO
AD	32.31	32.31			10.77	10.77	10.77									
AE																
AFS		38.07	12.69						25.38							
AGDS	5.4															
AGFF		8.8														
AGF		115.4														
AGSS																
AG					0.15											
AOE		70.76						70.76								
AOR		68.46														136.92
AO		100.41					100.41									
ARS							10									
AR	11.56	5.78														5.78
ASR	0.34	0.34			0.17											
AS	140.0	70.0			140.0								70.0			
ATF	0.15					0.15										
ATS							3.66									
AVM																
AVT																
CGN	19.59	32.65														
CG	145.35	32.3	32.3	16.15	48.45		16.15	16.15								
CVN		492.3				246.15										
CV	542.31	542.31	180.77			361.54			180.77							
DDG	72.54	72.54	8.06		40.30	24.18	48.36						8.06	24.18		
DD963	35.0	40.0			5.0								10.0			
DD	16.92	16.92			33.84	33.84	16.92			16.92	8.46	16.92	33.84	33.84	8.46	8.46
FFG1	23.1	7.7			7.7	7.7										
FFG7						4.62										
FF	123.9	35.4	35.80		70.8	53.1	79.65			8.85		17.7		17.7		
LCC	32.7	32.7														
LHA	69.24	34.62														
LPA		9.6											9.6			
LPD	200.76	234.22											33.46			
LPH	100.38	133.84														
LSD	75.46															
LST	135.44												16.93			16.93
MSO	0.24				0.48	0.12						0.24	0.24			0.24
PG																
PH	0															
SSBN					12.32		7.7									
SSN	6.96	7.54			4.06		6.96	0.58								
SS	3.0						1.0	1.0						1.0		
LKA	101.55	67.7														33.85
TOTAL	1894.2	2302.67	269.62	16.15	374.04	742.17	301.58	88.49	206.15	25.77	8.46	34.86	182.13	76.72	8.46	202.18

AVERAGE DAILY BILGE WASTE USING NAVSEA DATA (BY HOMEPORT AND SHIP CLASS)
IN THOUSANDS OF GALLONS

SHIP CLASS	LITTLE CREEK	PERTH AMBOY	ST. PETERS-BURG	PORT-LAND ME	PANAMA CITY	W.S. EARLE	CON-CORD	OAK-LAND	WS CHARLES-TON	LA MADE-LLENA	GUAM	HOLY LOCH	ROTA	EVERETT	PORT HUENEME	NULL
AD																32.31
AE						26.16	104.64		26.16							
AFS								12.69								
AGDS																
AGFF																
AGF																
AGSS																
AG																
AOE																
AOR																
AO																100.41
ARS	8.0															
AR																
ASR																
AS										70.0	70.0	70.0	70.0			210.0
ATF	0.3													0.15	0.15	
ATS	1.83															
AVM															7.7	
AVT																
CGN																6.53
CG																16.15
CVN																246.15
CV																
DDG																
DD963																60.0
DD																
FFG1																
FFG7																41.58
FF																
LCC																
LHA																69.24
LPA																
LPD																
LPH																
LSD	64.68															
LST	169.3															
MSO	0.24	0.12	0.24	0.24	0.12											
PG	0.30															
PHM																0
SSBN																1.54
SSN																5.8
SS																
LKA																
TOTAL	244.65	0.12	0.24	0.24	0.12	26.16	104.64	12.69	26.16	70.0	70.0	70.0	70.0	0.15	7.85	789.71

AVERAGE DAILY BILGE WASTE USING PA ENGINEERING DATA (BY HOMEPORT AND SHIP CLASS)
IN THOUSANDS OF GALLONS

SHIP CLASS	SAN DIEGO	NOR-FOLK	YOKO-SUKA	GAETA	CHARLES-TON	MAY-PORT	PEARL HARBOR	BREMER-TON	ALA-MEDA	PORT-LAND OR	NEW ORLEANS	SEATTLE	LONG BEACH	PHILA-DEL-PHIA	TAMPA	SAN FRAN-CISCO
AD	15	15			5	5	5									
AE																
AFS		15	5						10							
AGDS	5															
AGFF		5														
AGF		5														
AGSS																
AG					5											
AOE		10						10								
AOR		10														20
AO		15					15									
ARS							25									
AR	10	5														5
ASR	10	10			5											
AS	10	5			10								5			
ATF	5					5										
ATS							10									
AVM																
AVT																
CGN	15	25														
CG	45	10	10	5	15		5	5								
CVN		82						41								
CV	123	123	41			82			41							
DDG	45	45	5		25	15	30						5	15		
DD963	35	40			5								10			
DD	10	10			20	20	10			10	5	10	20	20	5	5
FFG1	15	5			5	5										
FFG7						5										
FF	70	20	20		40	30	45			5		10		10		
LCC	5	5														
LHA	10	5														
LPA		5											5			
LPD	30	35											5			
LPH	15	20														
LSD	35															
LST	40												5			5
MSO	10				20	5						10	10			10
PG																
PHM	5															
SSBN					80		50									
SSN	60	65			35		60	5								
SS	15						5	5						5		
LKA	15	10														5
TOTAL	653	600	81	5	275	172	260	66	51	15	5	30	65	50	5	50

AVERAGE DAILY BILGE WASTE USING PA ENGINEERING DATA (BY HOMEPORT AND SHIP CLASS)
IN THOUSANDS OF GALLONS

SHIP CLASS	PENSA-COLA	NEW YORK	NEW LON-DON	BAY-ONNE	NEW PORT RI	BALTI-MORE	BROOK-LYN	TACO-MA	BOSTON	BATH	GROTON	SUBIC BAY	VALLE-JO	PASCA-GOULA	PORTS, NH	NEW PORT-NEWS
AD																
AE							5									
AFS																
AGDS																
AGFF																
AGF																
AGSS													5			
AG																
AOE																
AOR							5									
AO																
ARS																
AR																
ASR									5							
AS			5													
ATF																
ATS																
AVM																
AVT	5															
CGN																
CG																
CVN																
CV																
DDG																
DD963																
DD	5	5	5	5	20	5	5	5	5							
FFG1																
FFG7																
FF					5	5			20	10						
LCC																
LHA																
LPA																
LPD																
LPH																
LSD																
LST																
MSO					10			5							5	
PG																
PHM																
SSBN											55				15	5
SSN			40								60		30	5		
SS											5	5				
LKA																
TOTAL	10	5	50	5	35	10	15	10	30	10	120	5	35	5	20	5

AVERAGE DAILY BILGE WASTE USING PA ENGINEERING DATA (BY HOMEPORT AND SHIP CLASS)
IN THOUSANDS OF GALLONS

SHIP CLASS	LITTLE CREEK	PERTH AMBOY	ST. PETERS-BURG	PORT LAND ME	PANAMA CITY	W. S. EARLE	CON-CORD	OAK-LAND	U. S. CHARLES-TON	LA MADEL-LENA	GUAM	HOLY LOCH	ROTA	EVERETT	PORT HUE-NEME	NULL
AD																15
AE						10	40		10							
AFS								5								
AGDS																
AGFF																
AGF																
AGSS																
AG																
AOE																
AOR																
AO																15
ARS	20															
AR																
ASR																
AS										5	5	5	5			15
ATF	10													5	5	
ATS	5															
AVM															5	
AVT																
CGN																5
CG																5
CVN																41
CV																
DDG																
DD963																60
DD																
FFG1																
FFG7																65
FF																
LCC																
LHA																10
LPA																
LPD																
LPH																
LSD	30															
LST	50															
MSO	10	5	10	10	5											
PG	10															
PHM																5
SSBN																10
SSN																50
SS																
LKA																
TOTAL	135	5	10	10	5	10	40	5	10	5	5	5	5	5	10	276

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

oily waste; waste oil; treatment systems; life-cycle costs; estimations; methodology evaluation.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the results of an evaluation of NEPTUNE, a computer based model designed to estimate life-cycle costs for oily waste/waste oil collection, transfer, treatment and disposal systems. We have found that the program can meet its stated goal of 25 percent relative accuracy, and can also be a valuable aid in identifying oily waste sources.

It was determined that a formal error propogation analysis, omitted during program development, would provide helpful data to the user and indicate

20. (Cont'd). the likely confidence levels of the estimates. The principal recommendation of this report is that this be completed and that new tables for error terms be incorporated into the model.

The procedure used to determine the regression relationships ignored the issue of the weight of the points. In some cases, therefore, the smaller values of cost or effluent volume were fitted better while in other cases the larger values were fitted better. The correct procedure would be to assign a priori weights to the data according to their anticipated frequency in the estimation case description.

There would be advantages also to allowing a regression within the model over user input statistics to permit local best fits to be obtained. This would contribute towards expanding the possible applications of the program and its derivatives into the design phases.

An analysis of oily waste sources was performed and it was determined that bilge dominates the effluent volume, contributing more than 99 percent of the total. Two estimates of the Navy-wide bilge generation rate were made yielding values of 3.34 and 8.04 million gallons per day using P. A. Engineering and NAVSEA data respectively. The former figure is probably more accurate as it is derived from more recent data.

Using bilge volume as a basis, Navy-wide life-cycle cost estimates of 45.45 million dollars per year and 31.84 million dollars per year were obtained for the centralized and shipboard treatments respectively. The corresponding figures obtained by another worker using independent weights were 38.85 and 30.77 million dollars per year. After reviewing the surrounding factors, however, it was not possible to establish significant cost savings in the shipboard system.

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